United States
Department of
Agriculture

Forest
Service

**Southwestern
Region**

Forestry
and Forest
Health

R3-02-02

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June 2002

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Emergence of Latent Dwarf Mistletoe Infection in Young Ponderosa Pine Regeneration: 10-Year Monitoring of the Whitetail A & B Project Area at Mescalero

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June 2002

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Abstract

Ten year post-treatment results are presented for a dwarf mistletoe control project on the Mescalero Apache Reservation. Over 1200 ponderosa pine seedlings and young saplings have been monitored in an area treated (essentially clearcut) for severe dwarf mistletoe infection in 1991 and 1992. By 2001, fifteen percent of these small trees had developed visible infection (plot range 6.3 to 24.7 percent). Nearly all of the infections were latent (present but invisible) at the time of treatment. The proportion of trees with latent infection increased with increasing height. Only about five percent of trees below "knee-high" at the time of treatment have developed infections. Eighteen percent of the infections detected to date did not sprout until six to nine years after treatment. Management implications are discussed.

Introduction

The Whitetail A & B area on the Mescalero Apache Reservation contained severe and extensive dwarf mistletoe infestation prior to aggressive treatment in 1991 and 1992. In 1995 we installed a set of plots in this area to monitor the development of latent mistletoe infections (i.e. infections present but not visible at the time of treatment) in the young natural regeneration. The main objective of these plots was to help determine and document the need for follow-up sanitation.

We had originally intended to install 3 or 4 one-half acre plots, but our summer crew was able to install a total of 9 plots, providing a sample of over 1200 ponderosa pine seedlings and young saplings. Since little information is available on infection of very young ponderosa pine, the extra plots provided an opportunity to better determine infection rates for small trees and compare site to site variation in infection.

These plots were first remeasured in 1998, six years after treatment. Results at that time indicated that there was probably a significant amount of additional latent infection remaining, so it was decided to remeasure the plots the plots again in 2001. This report contains the latest results of this monitoring effort.

Since implementation of the Whitetail A & B project in 1992, about 6000 acres of severely infected stands have been treated under similar prescriptions at Mescalero. Results from the Whitetail A & B plots should have application for management of these areas. Many of these stands have been cut according to a prescription now known locally as the "knee-high rule." An indirect estimate of the residual infection expected using the knee-high rule can be obtained using data from the Whitetail A & B plots.

Stand and Treatment

Prior to treatment, most of the 120 acre Whitetail A & B project area was an open, multistoried forest of nearly pure ponderosa pine. It contained roughly 40 to 50 BA of small sawtimber and poles, and fairly abundant (but irregularly distributed) seedlings and saplings. As part of the 12,000 acre Whitetail logging unit, the site had a history of previous harvest and thinning activities, including at least some effort to control dwarf mistletoe (Hawksworth and Lusher 1956). The site is a ponderosa pine/gambel oak habitat type of moderate site quality. Topography is gently rolling with a predominantly westerly aspect; elevation averages about 7750 feet.

The majority of the area (about 80 acres) had severe dwarf mistletoe infection prior to treatment. Nearly all of the sawtimber and poles in this area were visibly infected—most of them at least moderately to heavily infected. Significant amounts of visible infection were also appearing in the smaller size classes. This area was essentially clearcut. Commercial logging was conducted during the winter of 1991/92, and non-commercial felling during the summer of 1992.

In about half of the clearcut—area A—all trees over three feet tall were cut. Visibly infected trees less than three feet tall were cut; a few were pruned. In the remainder of the clearcut—area B—all sawtimber and poles were removed, but many taller saplings free of visible infection were retained.

A broadcast burn was conducted throughout most of the A and B areas in the fall of 1992, mainly to remove excess slash and facilitate planting of understocked portions. The fire killed some of the existing natural regeneration, but much of it survived. Both areas were interplanted with pine seedlings in February 1993. Planting crews encountered and cut a few additional infected trees.

The remainder of the project area, which included the lower slopes along the north and west sides and the northeast corner, had less severe infection. These areas were selectively thinned, removing most visibly infected trees. This helped limit the visual impact of the project.

Sampling Methods

Nine 0.5 acre circular plots were installed in portions of the clearcut that had relatively abundant natural regeneration. All live ponderosa pine over one foot tall were tagged and examined carefully for infection. Tree heights were recorded to the nearest half-foot. Azimuth and distance from plot center to each sample tree was measured and recorded to help facilitate re-location.

All visibly infected trees on the plots were either cut or pruned. Trees were pruned if mistletoe shoots were at least 6" from the main stem; otherwise the trees were cut. Visible infections outside the plots were also removed for about 30 feet beyond the plot borders to prevent spread back into the plots. All new visible mistletoe infections on and surrounding each plot were removed in this manner when the plots were revisited in 1998 and 2001.

A total of 1239 trees were sampled on the nine plots. Nearly all of them were located within 20 to 30 feet of one or more recently cut stumps. Based on pre-treatment conditions, it can be assumed that most of the sample trees had been well within the range of dwarf mistletoe infection sources prior to the treatment.

Results

By 2001, nine years after the treatment, 15 percent of the sample trees had become visibly infected (Table 1.) This includes all trees that were visibly infected when the plots were set up in 1995 plus all *additional* visibly infected trees found in 1998 and 2001, and accounts for mortality. All infections are assumed to have been latent (present

but invisible) when the stand was treated in 1992.[1] Few if any new infections could have occurred *after* 1992 because of the aggressive treatment that year, the resulting stand structure, and the subsequent removal of all emerging latent infections.[2]

Table 1. Development of latent infections, 1992 to 2001.

Plot #	# live trees 1995	# trees visibly infected 1995	# trees visibly infected 1998	# trees visibly infected 2001	Cumulative % infected
1	83	5	2	2	11.7
2	163	12	4	8	15.7
3	243	13	11	4	12.3
4	111	13	7	3	21.1
5	116	8	6	2	15.0
6	112	0	5	1	6.3
7	64	4	4	0	12.7
8	101	5	15	4	24.7
9	246	11	16	8	15.4
Total	**1239**	**71**	**70**	**32**	**15.0**

Plots 1, 6, and 7 are located in the A area, where all trees over three feet were cut. On these plots, 9.8% of the trees have developed visible infection. The other plots were located in the B area, where some taller saplings were retained. Here 16.3% of the trees have developed visible infection. The overall severity of infection prior to treatment was probably somewhat higher in the A area than the B area.

The timing of the emergence of latent infection has been quite variable from plot to plot. On five of the plots, more infected trees were detected in 1995 (3 years after treatment) than in 1998 (6 years after treatment), but on three of the plots the reverse was true. The reason(s) for this variation are not known. Overall, about the same number of infections were detected in 1998 as in 1995.

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[1] A few of the infections detected when the plots were set up in 1995 may have been missed when the stand was treated in 1992. Similarly, a few of those detected in 1998 may have been overlooked in 1995. Any such discrepancies are probably very minor, and, at least from a practical or operational standpoint, insignificant.

[2] None of the infections detected in 1998 or 2001 occurred on host material that developed after 1992. This supports the idea that no additional infections have taken place on the plots since the treatment. Note that recent growth is more susceptible to infection than older growth (Hawksworth 1961), so if any additional infection occurred, at least some of it could be expected on younger host material.

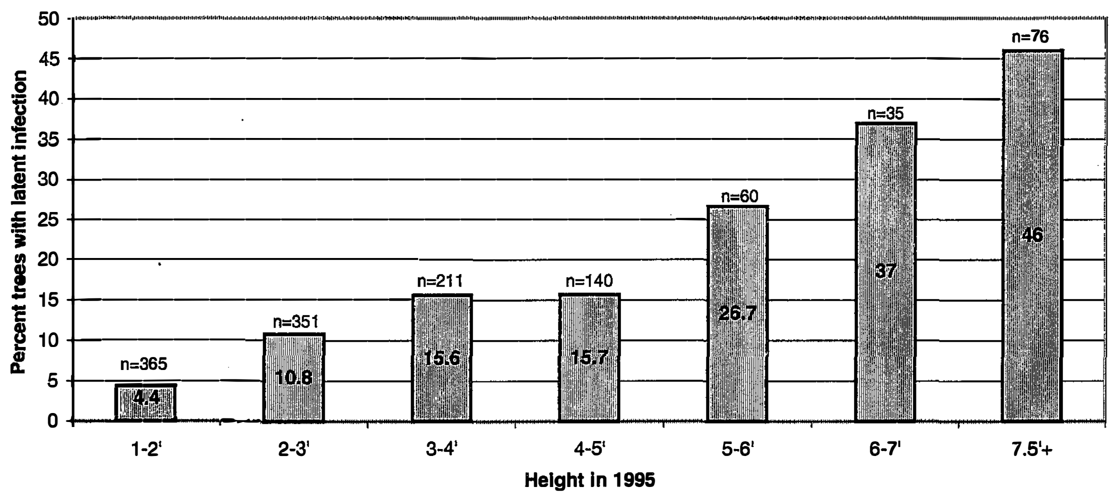
The emergence of new infections tapered off on most plots between 1998 and 2001. However, 32 additional infected trees—about 18% of those found to date—were detected in 2001. The dwarf mistletoe on these trees apparently did not sprout until 6 to 9 years after the treatment.

Latent Infection vs. Tree Height

The proportion of trees with latent infections clearly increased with increasing height (Figure 1). The taller saplings were much more likely to harbor latent infection than the smaller trees, especially those below 2 feet. Note that the heights shown in Figure 1 are those measured in 1995 when the plots were set up.

Ages of these young trees were not measured, but most trees three feet tall and under when the plots were set up were less than 10 years old at the time of treatment. A few of the sample trees were probably infected as early as age two or three.

Figure 1. Proportion of trees with latent infections, by height class.



Test of the "Knee-High Rule"

Since treatment of the Whitetail A & B area in 1992, many severely infested stands at Mescalero have been cut according to a "knee-high rule." As implied, this entails cutting all host trees taller than knee high, (about 1.5 to 2.0 feet tall, depending on the person). This aggressive prescription has been feasible in areas having a good cohort of very young regeneration and should provide a lower level of residual infection than in the Whitetail A and B area.

In Whitetail A & B, virtually all trees 1 to 2 feet in 1995, and many of those 2 to 3 feet, would have been below "knee-high" at the time of treatment. Trees up to 2.5 feet in 1995 may best represent those below knee height in 1992. To date, 31 of these trees (5.9%) have developed visible infection. Rates vary from 1.3% (Plot 3) to 13.8% (Plot 8).

Some additional latent infection will likely develop on these smaller trees, but infections *have* tapered off. Infections were detected on 15 of these trees in 1995, nine in 1998, and seven in 2001.

Plot data do not include natural regeneration less than one foot tall in 1995. These trees have increased the total stocking on several of the plots significantly, and, as might be expected, very little visible infection has developed on them. Thus, infection rates for all trees below knee-high—including these additional ones-- are probably lower than the above values.

Overall rates of infection

The overall rate of infection in each size class would include trees that were visibly infected before the treatment as well as those with latent infections. Because many visibly infected saplings were cut during the 1992 treatment, before the plots were set up, the overall rates of infection cannot be determined. Nevertheless, based on previous studies as well as on observations made in the project area prior to treatment, it can safely be assumed that the proportion of trees that were visibly infected before the treatment also increased with increasing height.

The overall rate of infection for the taller trees would have been much greater than what is shown in Figure 1. For saplings greater than 6 feet tall, the overall rate of infection (visible plus latent) probably exceeded 80%. The smallest trees, at least those in the 1-2 foot class, would have overall infection rates only slightly higher than what is shown in Figure 1 because most infections in these trees were latent at the time of treatment.

Pruning

Thirty-three infected trees were pruned in 1995. Eight of these were visibly infected by 1998, and six more by 2001. Seventeen of these pruned trees (52 percent) were still "clean" in 2001. (One of them was not found). Eighteen trees were pruned in 1998, 4 of which were visibly infected by 2001.[3]

At each remeasurement, the proportion of new infected trees that were "prunable" decreased. In 1995, 46% were prunable; in 1998, 26% were prunable, and in 2001, only 6% were prunable. After several years, nearly all of the remaining latent infections appeared on the trunk.

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[3]Agency crews had also pruned some infected trees during the 1992 treatment. In an attempt to determine the efficacy of the 1992 pruning, I had instructed my crew to tally all sample trees with old pruning scars. They recorded a total of 25 pruned trees on the nine plots (about 2% of the total sample). However, none of these 25 trees were recorded as visibly infected. Because at least *some* of the trees pruned in 1992 should have developed visible infection by 1995, it became apparent that the crew had not looked for pruning scars on visibly infected trees. Therefore, the results of the 1992 pruning could not be determined. Note that to avoid overly complicating analyses in this study, the 25 trees recorded as pruned in 1992 have been treated the same as the other 1214 sample trees. This has an almost negligible effect on the overall results, since these trees make up such a small proportion of the sample.

Tree Mortality

Sixty-three (5.1 percent) of the sample trees died between 1995 and 1998, and an additional 20 (1.6 percent) between 1998 and 2001. Rodents (probably mice or voles) and presumably drought caused most of the mortality. Signs of both armillaria and annosus root diseases were found on a few of the dead trees, and probably some of the mortality can be attributed to these fungi. Little or no mortality has been caused by dwarf mistletoe infection, although the periodic removal of visibly infected trees has minimized this possibility.

Discussion

Trunk Infections

Trunk infections can be very common on young trees in heavily-infected ponderosa pine stands. A high proportion of the infections in very young regeneration are probably from mistletoe seeds landing and germinating directly on the main leaders, resulting in visible trunk infections a few years later. Observations on these plots suggest that trunk infections tend to develop more slowly, and take longer to sprout, than those on branches. Moreover, some trunk infections on young trees actually originate on branches. These may not sprout until they enter the trunk, especially if they originate on branches that die from natural pruning or are otherwise of low vigor. In such situations the latent period will certainly be extended.

It has been reported that trunk infections will usually kill very small trees (Hawksworth and Weins 1996). Very little evidence of this has been observed on these plots, or within the clearcut outside the plots. (It is certainly possible that some seedlings were killed by trunk infections before the plots were set up.) Trunk infections are probably more likely to kill small trees in the understory of dense stands, where suppression is a factor, than in open stands. In open-grown regeneration, it appears that most young trees with trunk infections can easily live long enough to infect neighboring regeneration.

Latent Period

Inoculation studies described in Hawksworth's 1961 *Dwarfmistletoe of Ponderosa Pine in the Southwest* have provided the best and most widely used information on latent infection for this species of dwarf mistletoe. These studies indicated that over 90 percent of infections develop visible shoots within five years. Results of our 1998 remeasurement suggested a more extended latent period. The 2001 remeasurement seems to confirm this.

Our results on the emergence of latent infections are not directly comparable to those in the inoculation studies, however. This is mostly because many visibly infected saplings were cut during the 1992 treatment, and no information on these trees is available or

included in our results. Probably the infections on these trees tended to develop shoots more rapidly than those on the remaining trees.

The infections on these plots must have originated over a period of several years prior to the treatment in 1992. Thus, infections detected in 2001 were latent for *at least* six to nine years. Some were probably latent for more than nine years; additional monitoring may confirm some older infections. The longest latent period previously documented for ponderosa pine dwarf mistletoe is eight years (Hawksworth 1961, Hawksworth and Wiens 1996).

It appears that only around 60 to 70 percent of the infections that develop after sanitation treatment become visible within five years. Early studies on dwarf mistletoe control at the Fort Valley Experimental Forest in northern Arizona, summarized in Gill and Hawksworth (1954), had suggested a prolonged latent period following treatment, similar to what we are observing in Whitetail A & B at Mescalero.

Management Applications

A prolonged latent period is the main reason that complete eradication of dwarf mistletoe from forest stands is usually impractical. Ideally, the most effective mistletoe control strategy for severely infected areas would involve complete "stand replacement," i.e. clearcutting and/or burning to ground level, and replanting. However, given both the limited success of planting and the abundance of natural regeneration at Mescalero, management of the young advanced reproduction seems the best option for most severely infected stands. In most cases, the costs of "sanitizing" the natural regeneration will be much less than the costs of planting.

A follow-up treatment five years after initial treatment could potentially eliminate about two-thirds of the residual (latent) infection in young ponderosa pine regeneration in clearcut areas. Delaying follow-up until eight to ten years after initial treatment would allow a higher proportion of the latent infections to become visible, but would allow additional spread in the meantime. Relatively little spread should occur during the first five years after treatment if a good initial job of removing infections was accomplished; this should be especially true for stands treated under the "knee-high rule."

To insure a very low level of infection in these developing stands, two follow-up treatments—one at five years, and a second about five years later, should be a reasonable strategy. Sanitation of very young stands can be done at a fairly low cost, and would not generate much slash or sacrifice much accumulated growth. Very young stands offer some of the best opportunities to control dwarf mistletoe—opportunities that may not exist again for 100+ years.

After some practice, workers should be able to recognize infections on young trees quickly and efficiently. Nearly all of the infections will appear on the older portions of these small trees—on lower limbs or often directly on the main stem.

Pruning of young infected trees should only be attempted if the mistletoe plants are at least six to eight inches from the trunk (Hawksworth 1961); otherwise the trees should be cut. In adequately stocked areas, it is usually better to cut all infected trees rather than attempt any pruning, because some pruned trees will develop additional infections.

The first follow-up treatment in these young stands should be limited to removal of visibly infected trees (and perhaps severely deformed trees). Because of latent infections, it is usually best to delay thinning (spacing) of overstocked groups; otherwise many young crop trees may turn out to be infected after potential replacements have been cut. If needed, thinning could potentially be combined with a second follow-up, since nearly all latent infections will have developed by this time (10 years after initial treatment).

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